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(54) Title: MATERIAL AND METHOD TO DISSOCIATE WATER (57) Abstract <p>Material and method for the decomposition/dissociation of water into hydrogen and oxygen. The material comprises an amalgam of an alkali metal, mercury, and aluminum combined with a catalytically effective amount of an alloy comprising nickel and at least one metal selected from the group consisting of germanium, antimony, gallium, thallium, indium and bismuth.</p>		

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MATERIAL AND METHOD TO DISSOCIATE WATER

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of Application Serial No. 902,705, entitled MATERIAL AND METHOD FOR OBTAINING HYDROGEN AND OXYGEN BY DISSOCIATION OF WATER, filed on May 4, 1978; of Application Serial No. 902,708, entitled MATERIAL AND METHOD FOR OBTAINING HYDROGEN AND OXYGEN BY DISSOCIATION OF WATER, filed on May 4, 1978; of Application Serial No. 06/068,749, entitled MATERIAL AND METHOD FOR OBTAINING HYDROGEN BY DISSOCIATION OF WATER, filed on August 23, 1979; and of an application having attorney's indicia AE-109, entitled MATERIAL AND METHOD TO DISSOCIATE WATER AT CONTROLLED RATES, filed on October 16, 1979; and is related to to an application having attorney's indicia AE-106, entitled HYDROGEN GENERATING APPARATUS AND METHOD, filed on October 16, 1979; and to Application Serial No. 06/056,994, entitled FUEL SYSTEM AND METHOD, filed on July 12, 1979.

BACKGROUND OF INVENTION

Field of Invention

This invention relates to a material for and method of effecting the decomposition/dissociation of water into hydrogen and oxygen.

The water is reacted with an amalgam of sodium, aluminum and mercury to form hydrogen and a metallic hydroxide denoted by the formula $\text{Na}_3\text{Al}(\text{OH})_6$ is unstable at

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the temperature of formation in the presence of a catalyst comprising nickel and at least one element selected from the group consisting of germanium, antimony, gallium, thallium, indium, and bismuth and breaks down to form
5 metallic sodium and aluminum thereby releasing oxygen and hydrogen.

Description of the Prior Art

It is well known in the prior art that the alkali
10 metals react with water to form hydrogen and the stable alkali metal hydroxide. The foregoing reaction is rapid, the heat generated intense and explosion of hydrogen ordinarily occurs. The result is an unsatisfactory and dangerous method of generating hydrogen. It is also well known
15 that alkali metal peroxides may be used for the generation of oxygen (see U. S. Patent 3,574,561).

Thermochemical cycles comprising metal-metalloid combinations for the generating of both hydrogen and oxygen are disclosed in U. S. Patent 3,969,495.

20 Closed cycle processes for dissociation of water into hydrogen and oxygen are disclosed in U. S. Patents 3,821,358, 3,928,549 and 4,011,305. Combinations of various metals in multistep processes for dissociation of water are, therefore, well known; however, the simple and
25 facile manner of producing hydrogen and oxygen utilizing an amalgam of alkali metal, aluminum and mercury combined with a catalytic alloy comprising nickel and at least one element selected from the group consisting of germanium, antimony, gallium, thallium, indium and bismuth has not
30 been heretofore appreciated.

DESCRIPTION OF THE INVENTION

The material I have found to be suitable for the generation of hydrogen and oxygen from water without spon-
35 taneous combustion of the resultant evolved hydrogen and

oxygen gases comprises an amalgam of (1) an alkali metal such as lithium, sodium, potassium, cesium, or combinations thereof, (2) aluminum and (3) mercury combined with a catalytic alloy comprising nickel and at least one element selected from the group consisting of germanium, antimony, gallium, thallium, indium and bismuth.

The particle size of the sodium and aluminum is such as to enable formation of an amalgam and may fall within the range of from about 10 to about 100 mesh. Most preferably, the particle size of the aluminum should be about 10 mesh. Alkali metal of 1/4" diameter is suitable. The particle size of either the alkali metal or aluminum is not critical since the foregoing metals and mercury readily intermix. The smaller the particle size, of course, the more rapid the mixing.

The atomic weight ratio of alkali metal to mercury is from about 1:100 to about 100:1 and the atomic weight ratio of alkali metal to aluminum is from about 1:100 to about 100:1. Preferably, the atomic weight ratio of alkali metal to mercury is from about 3:1 to about 1:1.5 and the atomic weight ratio of alkali metal to aluminum is from about 1:1 to about 3:1.

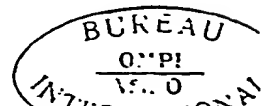
The amalgam of alkali metal, aluminum and mercury is combined with a catalytically active alloy which is present in a catalytically effective amount and, at the conditions of hydrogen generation, functions to regenerate amalgam to the active metallic state.

The catalyst/alloy is nickel and at least one element selected from the group consisting of germanium, antimony, gallium, thallium, indium and bismuth.

Preferably, the catalyst comprises nickel and at least one element selected from the group consisting of germanium, antimony, gallium, thallium, indium and bismuth.

Catalytic activity is further enhanced by the addition of minor amounts of zirconium and chromium.

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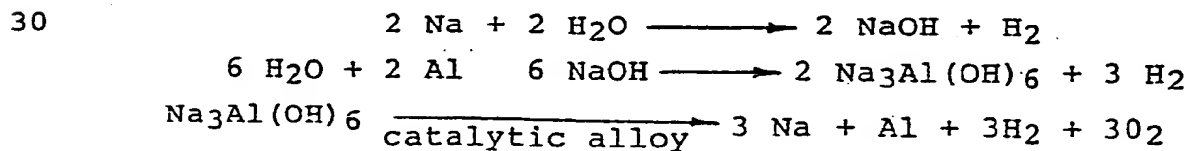
Silver and/or gold may be incorporated in the catalyst as an alloying element to lower the melting point of the alloy.

The alloy and amalgam may be combined in weight ratios of from about 1:1 to about 1:5 and preferably from about 1:2 to about 1:3.

In combining the alloy and amalgam, they may be compounded with an extender. The extender functions both to dilute the amalgam-catalytic alloy combination and to provide a heat sump for heat generated during the dissociation of water by contact with the combined amalgam and catalytic alloy. The extender is preferably bismuth; however, admixtures of tin and bismuth or gallium may also function as extenders.

The combination of amalgam and alloy or amalgam, alloy and extender is most suitably used in solid block form, hereinafter referred to as a reactor block. Where an extender is employed it may be present as a major constituent of the reactor block.

Although not wishing to be bound by the following explanation, it is believed that the water reacts with the alkali metal, e.g., sodium, and the aluminum liberating hydrogen and forming $\text{Na}_3\text{Al}(\text{OH})_6$. The $\text{Na}_3\text{Al}(\text{OH})_6$ is unstable, and in the presence of the alloy at the conditions of $\text{Na}_3\text{Al}(\text{OH})_6$ formation, the foregoing composition decomposes to form H_2 , O_2 and regenerated amalgam. The alloy apparently functions to catalyze the decomposition, and thereby extends the useful life of the amalgam. The process may be depicted as follows:



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It is preferred to include chromium as an additional component of the alloy. The incorporation of chromium as a component of the alloy appears to lower the heat of reaction. The chromium is generally present in the alloy
5 in an amount measured on a weight percent basis of said alloy of from about 0.7% to about 1.1% and preferably for about 0.8% to about 0.9%.

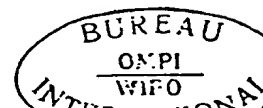
Each of the components of the alloy may be present in amounts of from about 0.4% by weight to about 28.5% by
10 weight based on the weight of the combined catalytic alloy and amalgam.

The preferred alloy comprises (1) nickel present in an amount of from about 3.5 to about 6.5% by weight, (2) bismuth present in an amount of from about 40.1 to about
15 68.7% by weight, (3) antimony present in an amount of from about 25.5 to about 42.5% by weight, (4) chromium present in an amount of from about 0.7 to about 1.1% by weight, (5) zirconium present in an amount of from about 4.1 to about 6.8% by weight and gold present in an amount
20 of from about 1.1 to about 1.9% by weight.

A specific example of said preferred alloy comprises about 4.5 weight percent nickel, about 53.7 weight percent bismuth, about 34.0 weight percent antimony, about 0.9
25 weight percent chromium, about 5.4 weight percent zirconium and about 1.5 weight percent gold.

The amalgam of sodium, aluminum and mercury is prepared utilizing any of the well known procedures with the added proviso that an inert atmosphere be employed. Amalgamation may be facilitated by utilization of an elevated
30 temperature, preferably around $200^{\circ}\text{C} \pm 10^{\circ}\text{C}$. The amalgam is preferably maintained at this elevated temperature for about 10 minutes where 100 grams are being processed, and the time is extended about 1 minute for each additional 100 gram aliquot.

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The resulting amalgam is cooled, generally to room temperature, utilizing an inert atmosphere. For this purpose either helium or argon are satisfactory. Cooling is preferably effected in a desiccator to insure that no water contacts the amalgam.

As in the preparation of the amalgam and all other steps in the method of manufacture of the various compositions of this invention, precaution must be taken during preparation to avoid the presence of oxygen because it has been observed that oxygen operates to poison the resultant material.

The preparation of the alloy selected may be in any well known manner having in mind the proviso that an inert atmosphere be maintained.

The alloy, upon solidification, and as a practical matter, upon cooling is ground into a powder, preferably a fine powder of about 10 mesh or less. Cooling may be effected in a dessicator to insure the absence of oxygen and moisture, whose presence is detrimental during preparation. Grinding/pulverizing may be effected in any well known manner including use of a ball, hammer and/or stamp mill.

The objective in combining the alloy and amalgam is to intimately admix the two respective components. The specific manner of catalysis is not known, but generally catalysis is a surface phenomenon and consistent therewith in the instant invention it appears that the catalysis is related to both particle size and nature as well as uniformity of mixture of the amalgam and catalytic alloy.

The amalgam and catalytic alloy may be used (1) in particulate form such as a floating bed, or other intimate dispersion, (2) in the form of porous mass which may be formed by compression or sintering or (3) as a solid mass by alloying of the amalgam and catalytic alloy. By

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alloying, it is meant that the amalgam and catalytic alloy are combined to form an admixture and alloyed under inert conditions at a temperature above the melting point of said admixture.

5 In either of the foregoing forms an extender, such as gallium, tin, bismuth, and preferably bismuth may be utilized. The extender functions to vary activity and as a heat sink to retain at least a portion of the heat of reaction of sodium aluminum hydroxide formation, whereby
10 catalysis of the unstable hydroxide to the metal and oxygen and hydrogen is enhanced.

Admixture of extender with the amalgam and catalytic alloy is effected utilizing the extender in a particulate form of comparable size to the other components, which
15 size is generally from about 10 to about 100 mesh.

EXAMPLE I

Preparation of Amalgam

An amalgam comprising 35.144 parts by weight of sodium,
20 13.749 parts by weight of aluminum and 51.107 parts by weight of mercury is formed in a graphite crucible in an inert atmosphere of argon at an elevated temperature of 200° C.

The resulting amalgam is cooled to room temperature
25 in a dessicator in an inert argon atmosphere. Thereafter, the amalgam is formed into a fine powder of about 10 mesh utilizing a ball mill. Grinding is effected in an inert atmosphere of argon.

It is important to prepare the amalgam in an inert
30 gas atmosphere to prevent hydroxide formation.

Preparation of Catalytic Alloy

53.7 parts by weight bismuth, 34.0 parts by weight antimony, 4.5 parts by weight nickel, 1.5 parts by weight gold, 5.4 parts by weight zirconium and 0.9 parts by weight
35 chromium are introduced into a graphite crucible which is

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thereafter placed in an oven and heated to melting in an inert atmosphere of helium to form an alloy of said metals.

The resulting alloy is cooled in a dessicator to about room temperature in an inert helium atmosphere.

5 Thereafter the amalgam is formed into a fine powder of about 10 mesh or less utilizing a ball mill. Grinding is effected in an inert atmosphere of helium.

The inert atmosphere is used to prevent oxidation of the alloy.

10 Formation of Intimate Amalgam and
 Catalytic Alloy Admixture

Three parts by weight of powdered amalgam is admixed with one part by weight powdered alloy in an inert atmosphere to obtain a uniform mixture of the amalgam and catalytic alloy.

The admixture may be utilized by passing steam upwardly therethrough whereby steam is dissociated into hydrogen and oxygen.

20 Formation of Reactor Block
Comprising Amalgam and Catalytic Alloy

Three parts by weight of powdered amalgam is admixed with one part by weight powdered alloy. The weighing and blending is effected in an inert atmosphere.

25 After blending to provide a uniform mixture, the
resultant mixture is compressed to form a solid mass by
application of pressure of about 40,000 pounds per square
inch in a graphite mold conforming to the desired shape
of the finished product. The mold utilized produces a
30 cubical block.

The resulting block is heated to an elevated temperature of about 10° C above the melting point of the mass and maintained at said temperature for about 10±1 minutes. In the oven utilized for heating, an inert at-

mosphere, is maintained. Thereafter the mass comprised of amalgam and alloy is transferred to a dessicator wherein an inert atmosphere is maintained and the mass is allowed to cool. Upon cooling the resulting block is ready for use.

The entire foregoing procedure should be carried out in an inert atmosphere such as helium or argon and in the absence of contaminants. Oxidation of the metallic components and/or hydroxide formation will "poison" the resulting reactor block and reduce the activity thereof. Moreover, during the steps of the process operated at elevated temperature, the presence of any oxygen will cause the mass to ignite.

Formation of Reactor Block Comprising Amalgam, Catalytic Alloy and Extender

The amalgam and alloy prepared above and an extender of gallium are admixed in the following proportions:

- 21.775 parts by weight amalgam.
- 9.225 parts by weight alloy.
- 69.0 parts by weight gallium.

The weighing and blending of the foregoing metallic compounds should be done in an inert atmosphere.

After blending to provide a uniform mixture, the resultant mixture is compressed to form a solid mass by application of pressure of about 40,000 pounds per square inch in a graphite mold conforming to the desired shape of the finished product. The compressed mass in a crucible conforming to the shape thereof is heated to an elevated temperature of about 10° C. above the melting point of the mass and this temperature is maintained for about 10±1 minutes. In the oven utilized for heating, an inert atmosphere is maintained. Thereafter the crucible

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and its contents are transferred to a desiccator wherein an inert atmosphere is maintained. Upon cooling the resulting block is ready for use.

The entire foregoing procedure should be carried out under an inert atmosphere such as helium or argon and in the absence of contaminants. Oxidation of the metallic components and/or hydroxide formation will "poison" the resulting reactor block and reduce the activity thereof. Moreover, during the steps of the process operated at elevated temperature, the presence of any oxygen will cause the mass to ignite.

The reactor blocks are contacted with a fine spray of water at about room temperature in an atmospheric environment. The gaseous effluent from said contact comprises hydrogen and oxygen and burns when subjected to electrical sparking. The volume of gas evolved is dependent on reactor block surface area and the volume of water impinging thereon. Generally a 2.5 square cm surface will react with 0.10 gallons of water per minute.

20

EXAMPLE II

Preparation of Amalgam

An amalgam comprising 37.688 parts by weight of aluminum, 32.112 parts by weight sodium and 30.2 parts by weight mercury is formed in a graphite crucible in an inert atmosphere of argon at an elevated temperature of 200° C.

The resulting amalgam is cooled to room temperature in a dessicator in an inert argon atmosphere. Thereafter, the amalgam is formed into a fine powder of about 10 mesh utilizing a ball mill. Grinding is effected in an inert atmosphere of argon.

It is important to prepare the amalgam in an inert gas atmosphere to prevent hydroxide formation.

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Preparation of Catalytic Alloy

57.5 parts by weight bismuth, 4.0 parts by weight nickel and 38.5 parts by weight germanium are introduced into a graphite crucible which is thereafter placed in an oven and heated to melting in an inert atmosphere of helium to form an alloy of said metals.

The resulting alloy is cooled in a desiccator to about room temperature in an inert helium atmosphere. Thereafter the amalgam is formed into a fine powder of about 10 mesh or less utilizing a ball mill. Grinding is effected in an inert atmosphere of helium.

The inert atmosphere is used to prevent oxidation of the alloy.

Formation of Intimate Amalgam and Catalytic Alloy Admixture

Three parts by weight of powdered amalgam is admixed with one part by weight powdered alloy in an inert atmosphere to obtain a uniform mixture of the amalgam and catalytic alloy.

The admixture may be utilized by passing steam upwardly therethrough whereby steam is dissociated into hydrogen and oxygen.

Formation of Reactor Block Comprising Amalgam and Catalytic Alloy

Three parts by weight of powdered amalgam is admixed with one part by weight powdered alloy. The weighing and blending is effected in an inert atmosphere.

After blending to provide a uniform mixture, the resultant mixture is compressed to form a solid mass by application of pressure of about 40,000 pounds per square inch in a graphite mold conforming to the desired shape of the finished product. The mold utilized produces a cubical block.

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The resulting block is heated to an elevated temperature of about 10°C above the melting point of the mass and maintained at said temperature for about 10 ± 1 minutes. In the oven utilized for heating, an inert atmosphere is maintained. Thereafter the mass comprised of amalgam and alloy is transferred to a dessicator wherein an inert atmosphere is maintained and the mass is allowed to cool. Upon cooling the resultant block is ready for use.

The entire foregoing procedure should be carried out in an inert atmosphere such as helium or argon and in the absence of contaminants. Oxidation of the metallic components and/or hydroxide formation will "poison" the resulting reactor block and reduce the activity thereof. Moreover, during the steps of the process operated at elevated temperature, the presence of any oxygen will cause the mass to ignite.

Formation of Reactor Block Comprising Amalgam, Catalytic Alloy and Extender

The amalgam and alloy prepared above and an extender of gallium are admixed in the following proportions:

21.775 parts by weight amalgam.

9.225 parts by weight alloy.

69.0 parts by weight gallium.

The weighing and blending of the foregoing metallic compounds should be done in an inert atmosphere.

After blending to provide a uniform mixture, the resultant mixture is compressed to form a solid mass by application of pressure of about 40,000 pounds per square inch in a graphite mold conforming to the desired shape of the finished product.

The compressed mass in a crucible conforming to the shape thereof is heated to an elevated temperature of about 10°C above the melting point of the mass and this temperature is maintained for about 10 ± 1 minutes. In the

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oven utilized for heating, an inert atmosphere is maintained. Thereafter the crucible and its contents are transferred to a desiccator wherein an inert atmosphere is maintained. Upon cooling the resultant block is ready
5 for use.

The entire foregoing procedure should be carried out under an inert atmosphere such as helium or argon and in the absence of contaminants. Oxidation of the metallic components and/or hydroxide formation will "poison" the
10 resulting reactor block and reduce the activity thereof. Moreover, during the steps of the process operated at elevated temperature, the presence of any oxygen will cause the mass to ignite.

The reactor blocks are contacted with a fine spray
15 of water at about room temperature in an atmospheric environment. The gaseous effluent from said contact comprises hydrogen and oxygen and burns when subjected to electrical sparking. The volume of gas evolved is dependent on the reactor block surface area and the volume of
20 water impinging thereon. Generally a 2.5 square cm surface will react with 0.14 gallons of water per minute.

EXAMPLE III

Preparation of Amalgam

An amalgam comprising 22.947 parts by weight of aluminum, 18.391 parts by weight sodium and 58.662 parts by
25 weight mercury is formed in a graphite crucible in an inert atmosphere of argon at an elevated temperature of 200°C.

The resulting amalgam is cooled to room temperature
30 in a dessicator in an inert argon atmosphere. Thereafter, the amalgam is formed into a fine powder of about 10 mesh utilizing a ball mill. Grinding is effected in an inert atmosphere of argon.

It is important to prepare the amalgam in an inert
35 gas atmosphere to prevent hydroxide formation.

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Preparation of Catalytic Alloy

61.264 parts by weight bismuth, 2.25 parts by weight nickel, 36.036 parts by weight antimony and 0.45 parts by weight germanium are introduced into a graphite crucible which is thereafter placed in an oven and heated to melting in an inert atmosphere of helium to form an alloy of said metals.

The resulting alloy is cooled in a desiccator to about room temperature in an inert helium atmosphere. Thereafter the amalgam is formed into a fine powder of about 10 mesh or less utilizing a ball mill. Grinding is effected in an inert atmosphere of helium.

The inert atmosphere is used to prevent oxidation of the alloy.

Formation of Intimate Amalgam and Catalytic Alloy Admixture

Three parts by weight of powdered amalgam is admixed with one part by weight powdered alloy in an inert atmosphere to obtain a uniform mixture of the amalgam and catalytic alloy.

The admixture may be utilized by immersion in water whereby water is dissociated into hydrogen and oxygen.

Formation of Reactor Block Comprising Amalgam and Catalytic Alloy

Three parts by weight of powdered amalgam is admixed with one part by weight powdered alloy. The weighing and blending is effected in inert atmosphere.

After blending to provide a uniform mixture, the resultant mixture is compressed to form a solid mass by application of pressure of about 40,000 pounds per square inch in a graphite mold conforming to the desired shape of the finished product. The mold utilized produces a cubical block.

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The resulting block is heated to an elevated temperature of about 10°C above the melting point of the mass and maintained at said temperature for about 10±1 minutes. In the oven utilized for heating, an inert atmosphere is maintained. Thereafter, the mass comprised of amalgam and alloy is transferred to a desiccator wherein an inert atmosphere is maintained and the mass is allowed to cool. Upon cooling, the resultant block is ready for use.

The entire foregoing procedure should be carried out in an inert atmosphere such as helium or argon and in the absence of contaminants. Oxidation of the metallic components and/or hydroxide formation will "poison" the resulting reactor block and reduce the activity thereof. Moreover, during the steps of the process operated at elevated temperature, the presence of any oxygen will cause the mass to ignite.

Formation of Reactor Block Comprising Amalgam, Catalytic Alloy and Extender

The amalgam and alloy prepared above and a powdered extender comprising 50 weight percent tin and 50 weight percent bismuth of about 10 mesh are admixed in the following proportions:

21.775 parts by weight amalgam.

9.225 parts by weight alloy.

69.0 parts by weight extender.

The weighing and blending of the foregoing metallic compounds should be done in an inert atmosphere.

After blending to provide a uniform mixture, the resultant mixture is compressed to form a solid mass by application of pressure of about 40,000 pounds per square inch in a graphite mold conforming to the desired shape of the finished product.

The compressed mass in a crucible conforming to the shape thereof is heated to an elevated temperature of about 10°C above the melting point of the mass and this temperature is maintained for about 10±1 minutes. In the oven utilized for heating, an inert atmosphere is maintained. Thereafter the crucible and its contents are transferred to a desiccator wherein an inert atmosphere is maintained. Upon cooling the resultant block is ready for use.

The entire foregoing procedure should be carried out under an inert atmosphere such as helium or argon and in the absence of contaminants. Oxidation of the metallic components and/or hydroxide formation will "poison" the resulting reactor block and reduce the activity thereof. Moreover, during the steps of the process operated at elevated temperature, the presence of any oxygen will cause the mass to ignite.

The reactor blocks are contacted with a fine spray of water at about room temperature in an atmospheric environment. The gaseous effluent from said contact comprises hydrogen and oxygen and burns when subjected to electrical sparking. The volume of gas evolved is dependent on the reactor block surface area and the volume of water impinging thereon. Generally a 2.5 square cm surface will react with 0.08 gallons of water per minute.

EXAMPLE IV

Preparation of Amalgam

An amalgam comprising 19.383 parts by weight aluminum, 31.068 parts by weight potassium and 49.549 parts by weight mercury is formed in a graphite crucible in an inert atmosphere of argon at an elevated temperature of 200°C.

The resulting amalgam is cooled to room temperature in a desiccator in an inert argon atmosphere. There-

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after, the amalgam is formed into a fine powder of about 10 mesh utilizing a ball mill. Grinding is effected in an inert atmosphere of argon.

5 It is important to prepare the amalgam in an inert gas atmosphere to prevent hydroxide formation.

Preparation of Catalytic Alloy

33.131 parts by weight bismuth, 12.145 parts by weight nickel, 42.847 parts by weight antimony, 2.429 parts by weight cadmium and 9.448 parts by weight zirconium are
10 introduced into a graphite crucible which is thereafter placed in an oven and heated to melting in an inert atmosphere of helium to form an alloy of said metals.

The resulting alloy is cooled in a desiccator to about room temperature in an inert helium atmosphere.
15 Thereafter the amalgam is formed into a fine powder of about 10 mesh or less utilizing a ball mill. Grinding is effected in an inert atmosphere of helium.

The inert atmosphere is used to prevent oxidation of the alloy.

20 Formation of Intimate Amalgam and Catalytic Alloy Admixture

Three parts by weight of powdered amalgam is admixed with one part by weight powdered alloy in an inert atmosphere to obtain a uniform mixture of the amalgam and catalytic alloy.

25 The admixture may be utilized by spraying water on the admixture whereby water is dissociated into hydrogen and oxygen.

Formation of Reactor Block Comprising Amalgam and Catalytic Alloy

30 Three parts by weight of powdered amalgam is admixed with one part by weight powdered alloy. The weighing and blending is effected in an inert atmosphere.

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After blending to provide a uniform mixture, the resultant mixture is compressed to form a solid mass by application of pressure of about 40,000 pounds per square inch in a graphite mold conforming to the desired shape of the finished product. The mold utilized produces a cubical block.

The resulting block is heated to an elevated temperature of about 10°C above the melting point of the mass and maintained at said temperature for about 10±1 minutes. In the oven utilized for heating, an inert atmosphere is maintained. Thereafter, the mass comprised of amalgam and alloy is transferred to a desiccator wherein an inert atmosphere is maintained and the mass is allowed to cool. Upon cooling, the resultant block is ready for use.

The entire foregoing procedure should be carried out in an inert atmosphere such as helium or argon and in the absence of contaminants. Oxidation of the metallic components and/or hydroxide formation will "poison" the resulting reactor block and reduce the activity thereof. Moreover, during the steps of the process operated at elevated temperature, the presence of any oxygen will cause the mass to ignite.

Formation of Reactor Block Comprising Amalgam, Catalytic Alloy and Extender

The amalgam and alloy prepared above and an extender of gallium are admixed in the following proportions:

- 21.775 parts by weight amalgam.
- 9.225 parts by weight alloy.
- 69.0 parts by weight gallium.

The weighing and blending of the foregoing metallic compounds should be done in an inert atmosphere.

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After blending to provide a uniform mixture, the resultant mixture is compressed to form a solid mass by application of pressure of about 40,000 pounds per square inch in a graphite mold conforming to the desired shape of the finished product.

5 The compressed mass in a crucible conforming to the shape thereof is heated to an elevated temperature of about 10°C above the melting point of the mass and this temperature is maintained for about 10±1 minutes. In the oven utilized for heating, an inert atmosphere is main-
10 tained. Thereafter, the crucible and its contents are transferred to a desiccator wherein an inert atmosphere is maintained. Upon cooling the resultant block is ready for use.

15 The entire foregoing procedure should be carried out under an inert atmosphere such as helium or argon and in the absence of contaminants. Oxidation of the metallic components and/or hydroxide formation will "poison" the resulting reactor block and reduce the activity thereof. Moreover, during the steps of the process operated at
20 elevated temperature, the presence of any oxygen will cause the mass to ignite.

25 The reactor blocks are contacted with a fine spray of water at about room temperature in an atmospheric environment. The gaseous effluent from said contact comprises hydrogen and oxygen and burns when subjected to electrical sparking. The volume of gas evolved is dependent on the reactor block surface area and the volume of water impinging thereon. Generally a 2.5 square cm surface will react with 0.10 gallons of water per minute.

30 EXAMPLE V

Preparation of Amalgam

An amalgam comprising 37.688 parts by weight aluminum, 32.112 parts by weight cesium and 30.2 parts by weight

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mercury is formed in a graphite crucible in an inert atmosphere of argon at an elevated temperature of 200°C.

The resulting amalgam is cooled to room temperature in a desiccator in an inert argon atmosphere. Thereafter, the amalgam is formed into a fine powder of about 10 mesh utilizing a ball mill. Grinding is effected in an inert atmosphere of argon.

It is important to prepare the amalgam in an inert gas atmosphere to prevent hydroxide formation.

10 Preparation of Catalytic Alloy

57.5 parts by weight bismuth, 4.0 parts by weight nickel and 38.5 parts by weight germanium are introduced into a graphite crucible which is thereafter placed in an oven and heated to melting in an inert atmosphere of helium to form an alloy of said metals.

The resulting alloy is cooled in a desiccator to about room temperature in an inert helium atmosphere. Thereafter the amalgam is formed into a fine powder of about 10 mesh or less utilizing a ball mill. Grinding is effected in an inert atmosphere of helium.

The inert atmosphere is used to prevent oxidation of the alloy.

25 Formation of Intimate Amalgam and Catalytic Alloy Admixture

Three parts by weight of powdered amalgam is admixed with one part by weight powdered alloy in an inert atmosphere to obtain a uniform mixture of the amalgam and catalytic alloy.

The admixture may be utilized by steam upwardly there-through whereby steam is dissociated into hydrogen and oxygen.

Formation of Reactor Block Comprising Amalgam and Catalytic Alloy

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Three parts by weight of powdered amalgam is admixed with one part by weight powdered alloy. The weighing and blending is effected in inert atmosphere.

After blending to provide a uniform mixture, the
5 resultant mixture is compressed to form a solid mass by application of pressure of about 40,000 pounds per square inch in a graphite mold conforming to the desired shape of the finished product. The mold utilized produces a cubical block.

10 The resulting block is heated to an elevated temperature of about 10°C above the melting point of the mass and maintained at said temperature for about 10±1 minutes. In the oven utilized for heating, an inert atmosphere is maintained. Thereafter, the mass com-
15 prised of amalgam and alloy is transferred to a desiccator wherein an inert atmosphere is maintained and the mass is allowed to cool. Upon cooling, the resultant block is ready for use.

The entire foregoing procedure should be carried
20 out in an inert atmosphere such as helium or argon and in the absence of contaminants. Oxidation of the metallic components and/or hydroxide formation will "poison" the resulting reactor block and reduce the activity thereof. Moreover, during the steps of the
25 process operated at elevated temperature, the presence of any oxygen will cause the mass to ignite.

Formation of Reactor Block Comprising Amalgam, Catalytic Alloy and Extender

30 The amalgam and alloy prepared above and an extender of powdered tin of about 10 mesh are admixed in the following proportions:

21.775 parts by weight amalgam.
9.225 parts by weight alloy.
35 69.0 parts by weight tin.

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The weighing and blending of the foregoing metallic compounds should be done in an inert atmosphere.

After blending to provide a uniform mixture, the resultant mixture is compressed to form a solid mass by application of pressure of about 40,000 pounds per square
5 inch in a graphite mold conforming to the desired shape of the finished product.

The compressed mass in a crucible conforming to the shape thereof is heated to an elevated temperature of about 10°C above the melting point of the mass and this
10 temperature is maintained for about 10±1 minutes. In the oven utilized for heating, an inert atmosphere is maintained. Thereafter the crucible and its contents are transferred to a desiccator wherein an inert atmosphere is maintained. Upon cooling the resultant block is ready
15 for use.

The entire foregoing procedure should be carried out under an inert atmosphere such as helium or argon and in the absence of contaminants. Oxidation of the metallic components and/or hydroxide formation will "poison" the
20 resulting reactor block and reduce the activity thereof. Moreover, during the steps of the process operated at elevated temperature, the presence of any oxygen will cause the mass to ignite.

The reactor blocks are contacted with a fine spray
25 of water at about room temperature in an atmospheric environment. The gaseous effluent from said contact comprises hydrogen and oxygen and burns when subjected to electrical sparking. The volume of gas evolved is dependent on the reactor block surface area and the volume of
30 water impinging thereon. Generally a 2.5 square cm surface will react with 0.14 gallons of water per minute.

Although the invention has been described in detail with respect to specific examples, it will be appreciated

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that various changes and modifications can be made by those skilled in the art within the scope of the invention as I have expressed in the following claims.

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I claim:

1. A material for the generation of hydrogen and oxygen from water which comprises an amalgam of an alkali metal, mercury and aluminum combined with an alloy of nickel and at least one element selected from the group consisting of germanium, antimony, gallium, thallium, indium and bismuth.
2. The material of Claim 1 further characterized in that the alkali metal is sodium or potassium.
3. The material of Claim 1 further characterized in that the alloy comprises nickel and at least one metal selected from the group consisting of germanium, antimony, gallium, thallium, indium and bismuth and the alkali metal of the amalgam is sodium.
4. The material of Claim 3 further characterized in that the alloy comprises nickel and thallium.
5. The material of Claim 3 further characterized in that the alloy comprises nickel and germanium.
6. The material of Claim 3 further characterized in that the alloy also contains a metal selected from the group consisting of zirconium, chromium and mixtures thereof.
7. The material of Claim 3 further characterized in that the alloy also contains a metal selected from the group consisting of silver, gold and mixtures thereof.

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8. The material of Claim 3 further comprising gallium.

9. The material of Claim 3 further characterized in that the ratio of alkali metal to mercury is from about 3:1 to about 1:1.5 and the atomic weight ratio of alkali metal to aluminum is from about 1:1 to about 3:1.

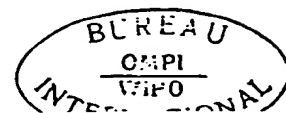
10. The material of Claim 3 further characterized in that the ratio, by weight, of alloy to amalgam is from about 1:1 to about 1:5.

11. The material of Claim 10 further characterized in that the ratio, by weight, of alloy to amalgam is about 1:1 to about 1:3.

12. The material of Claim 6 further characterized in that that alloy contains from about 0.7% to about 1.1% by weight chromium.

13. The material of Claim 3 further characterized in that each of the metallic components of the alloy present in said material is present in an amount of from about 0.4 to about 28.5 weight percent based upon the weight of
5 alloy and amalgam combined.

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14. The material of Claim 1 further characterized in that said alloy comprises nickel present in an amount of from about 3.5 to about 6.5% by weight, bismuth present in an amount of from about 40.1 to about 68.7% by weight, antimony present in an amount of from about 25.5 to about 42.5% by weight, chromium present in an amount of from about 0.7 to about 1.1% by weight, zirconium present in an amount of from about 4.1 to about 6.8% by weight and gold present in an amount of from about 1.1 to about 1.9% by weight.

15. The material of Claim 14 further characterized in that said alloy comprises about 4.5 weight percent nickel, about 53.7 weight percent bismuth, about 34.0 weight percent antimony, about 0.9 weight percent chromium, about 5.4 weight percent zirconium and about 1.5 weight percent gold.

16. The process for the generation of hydrogen and oxygen from water which comprises contacting water with an amalgam of an alkali metal, mercury and aluminum combined with a nickel containing alloy.

17. The process of Claim 16 further characterized in that the alkali metal is sodium, potassium or mixtures thereof.

18. The process of Claim 17 further characterized in that the alloy comprises nickel and at least one metal selected from the group consisting of germanium, antimony, gallium, thallium, indium and bismuth.

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19. The process of Claim 16 further characterized in that the alloy comprises nickel and at least one metal selected from the group consisting of germanium, antimony, gallium, thallium, indium and bismuth and the
5 alkali metal of the amalgam is sodium.

20. The process of Claim 19 further characterized in that the alloy comprises nickel and thallium.

21. The process of Claim 19 further characterized in that the alloy comprises nickel and germanium.

22. The process of Claim 19 further characterized in that the alloy also contains a metal selected from the group consisting of zirconium, chromium and mixtures thereof.

23. The process of Claim 19 further characterized in that the alloy also contains a metal selected from the group consisting of silver, gold and mixtures thereof.

24. The process of Claim 19 further comprising gallium.

25. The process of Claim 19 further characterized in that the atomic weight ratio of alkali metal to mercury is from about 3:1 to about 1:1.5 and the atomic weight ratio of alkali metal to aluminum is from about 1:1 to
5 about 3:1.

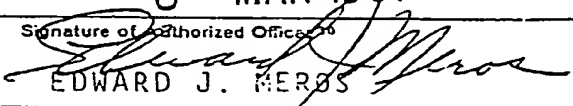
26. The process of Claim 19 further characterized in that the ratio, by weight, of alloy to amalgam is from about 1:1 to about 1:5.

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INTERNATIONAL SEARCH REPORT

International Application No PCT/US 81/00037

I. CLASSIFICATION F SUBJECT MATTER (if several classification symbols apply, indicate all) *		
According to International Patent Classification (IPC) or to both National Classification and IPC		
INT. CL. ³ C01B 13/02; C22C 7/00, 30/00		
US. CL. 75/134N; 423/579, 657		
II. FIELDS SEARCHED		
Minimum Documentation Searched *		
Classification System	Classification Symbols	
US	423/579, 648R, 657 75/134A, 134F, 134N, 138, 169	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched *		
III. DOCUMENTS CONSIDERED TO BE RELEVANT ¹⁴		
Category *	Citation of Document, ¹⁵ with indication, where appropriate, of the relevant passages ¹⁷	Relevant to Claim No. ¹⁸
A	US, A, 2,083,648, Published, 15 June 1937, Gorke	1-31
A	US, A, 2,837,408, Published, 03 June 1958, Sakowski	1-31
A	US, A, 3,313,598, Published, 11 April 1967, Gluckstein	1-31
A	US, A, 3,490,871, Published, 20 January 1970, Miller et al	1-31
A	US, A, 3,540,854, Published, 17 November 1970, Brooke et al	1-31
A	US, A, 3,833,357, Published, 03 September 1974, Bianche et al	1-31
A	US, A, 3,985,866, Published, 12 October 1976, Oda et al	1-31
P	US, A, 4,182,748, Published, 08 January 1980, Anderson	1-31
<p>* Special categories of cited documents: ¹⁶</p> <p>"A" document defining the general state of the art</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document cited for special reason other than those referred to in the other categories</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but on or after the priority date claimed</p> <p>"T" later document published on or after the international filing date or priority date and not in conflict with the application, but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance</p>		
IV. CERTIFICATION		
Date of the Actual Completion of the International Search *		Date of Mailing of this International Search Report *
24 MARCH 1981		30 MAR 1981
International Searching Authority *		Signature of Authorized Officer ¹⁹
ISA/US		EDWARD J. MERBS 

Form PCT/ISA/210 (second sheet) (October 1977)

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

P	US, A, 4,207,095, Published, 10 June 1980, Anderson	1-31
A	FR, B, 337,722, Published, 14 December 1903,	1-31
A	GB, A, 3188, Published, 30 September 1909,	1-31
A	WO, A, WO 79/01031, Published, 29 November 1979, Anderson	1-31

V. ☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE ¹⁰

This International search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. ☐ Claim numbers _____, because they relate to subject matter ¹² not required to be searched by this Authority, namely:

2. ☐ Claim numbers _____, because they relate to parts of the International application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out ¹³, specifically:

VI. ☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING ¹⁴

This International Searching Authority found multiple inventions in this International application as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this International search report covers all searchable claims of the International application.

2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the International application for which fees were paid, specifically claims:

3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

Remark on Protest

- ☐ The additional search fees were accompanied by applicant's protest.
☐ No protest accompanied the payment of additional search fees.

